Comparison Study of China's Eco-City Key Performance Indicator Systems

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ABSTRACT

China's rapid expansion of urbanisation level has inevitably brought severe pressures on resource conservation and environmental protection in Chinese cities. China has initiated policies, strategies and pilot projects at both national and local level to address these urban challenges. China appears in the frontline of reshaping and redeveloping the urban environments by promoting eco-city projects in recent years. Key performance indicator (KPI) system has been long time used for evaluating the success of urban projects. It has become a pivotal to guide the development of eco-city projects in China. This research paper first elaborates the current practice of using KPI systems as a mean to achieving eco-city development; and will then take a comparison study between various eco-city KPI systems currently being used in China. By identifying the common issues and specific issues from the reviewed KPI systems, this research indicates that there are some convergences amongst different systems. Future eco-city KPI systems may need to consider these common issues, and incorporate the local contexts in tandem.

Keywords: *KPI, eco-city, China, urban sustainability*

1. INTRODUCTION

A plethora of new city concepts have entered policy and planning discourse all in the wake of understanding that man cannot continue to prosper socially and economically without careful consideration of how it affects the environment. Experts suggest that our activities can no longer be sustained by 1 earth alone, with man's ecology resources and services being used at rate of 1.5 earths and if nothing is done would require more than 2 earths to replenish (Global Footprint Network 2013).

These concepts stem from various literature seeking to identify and achieve sustainability largely based on the triple bottom approach i.e. society, economy and environment, thus concepts such as sustainable cities, eco-cities, green cities, knowledge cities, smart cities, low carbon cities, resilience cities etc. have become titles which policy makers and developers aspire to achieve in pursuit of their own innovative contextual understanding of sustainability (de Jong, 2015). In order to achieve these cities, which represent at some level, a focus on all or particular dimension in sustainability, embedded eco-city wide projects have been embarked on by various nation particularly China. This concept is guided by the use indicators that identify important urban development issues, measure and set standard to be achieved in order to address sustainable development. However, de Jong (2015) identifies the interchangeable use and mix up in terminologies particularly by policy makers, planners and developers. A good example is the Chinese city of Guangzhou which is working with the Singaporean government on an urban development project named the Guangzhou Knowledge city yet the indicators used are noted to be "eco-city indicators"(Crane et al. 2012; de Jong et al. 2013). Another pitfall is the contextual nature which these indicators are noted to be developed by i.e. what might be noted as important in one region may not necessarily be deemed worthy in another e.g. compact design versus dispersed city design (Sharifi, 2013). This would suggest that indicators used to define Eco-cities for instance in Dongstan China may fall short of the mark in Shanghai. Nonetheless, indicators are noted to be the flywheel of this debate and by understanding their divergence and convergence we move closer to developing a set of standardised indicators which may be uniformly adopted in a region or sub region with particular emphasis on eco-cities. This then begs the question what are eco-city indicators, why such interchangeability? And how do we achieve parity?

In pursuit of answering this question, Neighborhood Sustainability Assessment Tools (NSATs) is also reviewed due to their international origins, and will be compared and contrasted with embedded eco-city frameworks within the region of China. As such this papers aims to tackle the question raised by practically identifying common and context specific indicators for eco-city, by establishing there points of convergence and divergence with case study focus of 6 tools, 4 city wide and 2 Neighborhood sustainability based tools within Location in ChinaContent

1.3 The eco – phenomenon

The ideology of an Eco system dates back to the 1970s by members of a voluntary organization Arcology group who strived to redevelop the concept cites living in tandem with nature (Dongtan 2008). Richard Register a co funder of urban ecology as well as the author of eco-city Berkely building cities for healthy future, defined eco-city as a conceptual city focused on the governance and living within the means of the natural environment (Premalatha et al. 2013). With looming environmental crises due to climate change as well, as other related issues such as health and energy poverty. The need for this concept and form of governance has been embraced by a myriad of academics policy makers and developers, with various attempts to interpret this general definition into practical and workable principles city wide construction and implementation (de Jong, 2015).

This venture, however, has not led to a definitive definition of eco-city as no agreeable definition has emerged till date (Premalatha et al. 2013; de Jong, 2015). Joss (2015) addresses the plausible reasons for this event. Firstly, it is suggested that diversity and ideas set in specific locales and governed by traditions as well as competition between various actors has led to the lack of cohesion. Secondly, this lack of coherence is simply an inevitable process towards agreeance, as the current phase could be seen as experimental to be followed by a phase of consolidation leading to more agreeable international norms. However, Joss (2015) also warned that this lack of agreeance by definition may lead to a conceptually vacuous principle i.e. lacking content with a threat of its application being applied for promotional and market fashionable services. Nonetheless, de Jong (2015), who also identifies the terminological fuzziness and confusion, stresses a need for clarification into distinct categories in relation to specific application. This argument invariably endorses the context dependency of eco city and its implementation of its indicators.

Joss (2015), however still argues that irrespective of its contextual proclivities another major reason for lack of definition is that eco cities are inherently future oriented. The reasoning here is that unlike other conceptual cities such as low carbon cities and resilient cities which more definitive in purpose, e.g. reduced pollution, renewable energy use, liveability etc. The form to which eco-city will take is still invisible looking towards the future. This argument is further solidified Richard Registers claims, suggesting that “eco city is an Ecological city, and no such city Exist”

Nonetheless, this should and has not stopped academics and practitioners from striving ever closer towards a unified definition as such Literature provides a myriad of definitions and indicators, qualitative and qualitative in nature which address the eco-city dimensions. For instance Newman and Jennings (2008) link eco cities closely with ecosystem thus creating indicators and principles based on that dimension, Lehman (2010, 2015) relates eco-city to urban development principles with emphasis on infrastructure and environmentally friendly buildings. Suzuki et al innovatively linked eco-city to economic prosperity with the terminology Eco2city, with the basis of its principle being ecologically considerate and economically viable. However de Jong (2015) argues that this leads the concept away from ecology and into a more sustainable arena. This can be seen in older publications by Roseland (1997, 2001) research, which identified 10 attributes pertinent to eco-city. Yet at least 5 out of the 10 refer to socio-economic issues.

- Prioritize land use and create a diverse and compact diverse, green and safe mixed use communities surrounding public transport facilities
- Should focus on transportation systems that would discourage driving and focus on proximity access
- Prioritize the remediation and restoration of damaged urban environment
- Prioritize affordable, safe and economically mixed housing
- Should promote equity and social justice and create improved opportunities for the impoverished
- Prioritize and focus on local, agriculture, community gardening and urban greening
- Promotion of recycling and resources conservation in addition to the reduction hazardous waste and pollution
- Should focus on ecologically derived and sound activities while discouraging those that increase pollution
- Focus on simple and environmentally conscious lifestyle while discouraging excessive consumption of material goods

- Prioritize the promotion of public awareness on the environment and bioregion through education and outreach programs

These descriptions while containing environmental and ecological prerogative have other concepts which promote economic prosperity and social consciousness. Over time the onset of eco-city has acquired a variety of conceptual meanings as shown above, especially as the process of eco-city drives towards policy development and practical implementation, especially in Asia and as such interweaving concepts such as social and economic dimension have become prominent, thus leading to softened environmental focus (de Jong 2013). Moving from the principles of Roseland and Register to the near future of post Brundtland report, the eco-city dimensions are noted to drive from the principles of triple bottom line approach or the 3 pillars of sustainability which is further conditioned by sustainability led dimensions such as urban design, governance and systems (World Commission on Environment and Development 1987). These dimensions are also generally categorized by indicators, specified with details, based on time frames and with a set of targets for the given project (Table 1). An example is the Tangshan Caofeidian International eco-city which has been in construction since 2009 and defines these dimensions with 141 indicators (Joss and Molella, 2013). With a target of 95% energy demand to be met by onsite renewable energy, 60% waste recycling and 20 targets for water preservation and recycling. Furthermore 68 of the indicator apply to city scale 14 on neighbourhoods scale and 25 at site level.

The main points to take away from the eco dimension is the lack or confusion in definition and indicators used to identify what can be termed eco-city however, in the post Brundtland report era, the 3 pillars will be one of the inherent concept used to categorise eco-cities. This process will however start with the understanding of eco-city development in China as the main topic of this paper followed by definition and understanding of underlying principles such as indicators and its utilization in pursuit of eco-city development. This will then provide the tools necessary to may comparison with other similar yet different frameworks such as BREEAM and LEED.

Environmental Sustainability	CO2/GHG	Reducing GHG emissions/energy consumption; promoting renewable energy generation
	Buildings	Reducing energy use; promoting carbon-neutral buildings
	Water	Reducing water consumption; improving water recycling
	Transport	Promoting integrated public transport
	Waste	Reducing waste; increasing waste recycling and waste-to energy generation
Economic sustainability	Biodiversity	Protecting green spaces; promoting biodiversity
	High-skilled, ‘green’ jobs and employability	Investing in the knowledge economy; attracting ‘green’ business
	Competitiveness and resilience	Enhancing international competitiveness; promoting community self-reliance
	Smart technology	Promoting ‘smart’ technological innovation
	Well-being	Improving individual and social well-being
	Housing	Providing affordable housing and mixed usage
	Urban agriculture	Promoting urban agriculture and local food networks
Social sustainability	Liveability	Creating socially inclusive, vibrant communities
	Equity	Fostering equity within and between generations
	Civic engagement	Encouraging participation in public life
	Cultural diversity	Promoting cultural engagement and diversity
Urban design and systems	Compactness	Increasing density of housing, along transport arteries

	Scale	Improving integration across neighbourhood, district, city, and regional levels
	Ecosystems management	Improving information management of urban infrastructure and systems (water, energy, etc.)
Urban governance	Policy coordination	Enhancing multilevel policy coordination
	Public–private partnerships	Promoting partnerships involving public, private, and nongovernmental actors
	Political accountability	Ensuring transparency, openness, and participation; collaborative planning

Table 1: Eco-city dimensions: general dimensions and related targets, based on a sustainability 'triple bottom line' applied to the urban context (Reference: Joss 2015)

1.4 Eco-city development in China

China is undergoing the largest scale of urbanisation in history and at an unprecedented pace. Between 1991 and 2012, China's urban population has increased from 302 to 712 million, or 26.4% to 52.6% in percentage terms (Table 1-2, China Statistical Yearbook 2013). To accommodate the increased population in cities, the built up urban areas have expanded from 12,856 to 45,566 square kilometers over the same period, an increase of 3.5 times greater in about two decades (Table 12-3, China Statistical Yearbook 2013). Also a more radical increase may be expected since urbanization is considered as a major development strategy by the Chinese governments to maintain long-term economic growth. The International Energy Agency (IEA 2012:39) has projected an urbanization rate of 65% by 2035, resulting in an annual increase of 14 million urban populations to reach this predicted ratio.

Cities in general and the built environment in particular, during their life-cycle, have a significant environmental impact both at local and global levels (Graham 2004:12; Girardet 2003:5). The rapid expansion of urbanization level has inevitably brought severe pressures on resource conservation and environmental protection in Chinese cities. The increasing pollution, traffic and energy consumption in the urban areas are becoming alerting matters in China. Only 8, out of 74 major Chinese cities, have satisfied the national air quality standards in 2014 (MEP, 2015). Recognizing these resource and environmental constraints, and moreover, the significance of developing a "resource-conserving and environmental friendly society", China has initiated policies, strategies and pilot projects at both national and local level to address the urban challenges.

Conventionally sustainable city efforts have been focused on individual issues such as urban energy, urban transport, land use, wastes, water and urban health. In recent years there is a growing interest in China to find a new integrated model for urban development as a whole. Effort to create such a new urban development model is manifested in the form of developing eco-cities.

China appears in the frontline of reshaping and redeveloping the urban environments (Joss et al 2011; Zhou et al. 2015; Flynn et al. 2016). Currently there are around 280 Chinese cities that have declared an ambition to develop "eco-city" or "low carbon city" (China Society for Urban Studies 2012, p10). A global survey conducted by the University of Westminster in 2011 recognised 25 eco-city projects in China according to the methodical criteria in that research. This makes china the country with the largest number of eco-city projects, followed by the USA with 17, and the UK and Japan with 16 each (Joss et al. 2011).

China's 12th Five Year Plan for Green Building and Green Eco-city Development, issued by the Ministry of Housing and Urban and Rural Development (MOHURD) in March 2013, requires selection of 100 new urban areas (e.g. new urban districts, industrial park, hi-tech zones), with a minimum size of 1.5 square kilometres, for pilot demonstration of eco-city concept. Till now, throughout the country three batches of city projects, totalling 19, were launched as the national level eco-city pilot projects by. Financial support has been provided to these projects from the Chinese central government. Table 2 gives some basic information about the first batch of national level eco-city pilot projects.

Eco-City projects	Area (km^2)	Projected population (k)	Current status
Sino-Singapore Tianjin Eco-City	30	350	Being constructed and operated
Tangshan Eco-City	150	1000	Being constructed and operated
Wuxi Eco-City	150	1000	Being constructed and operated
Changsha Eco-City	7.6	178	Being constructed and operated
Shenzhen Brightness New District	156	800	Being constructed and operated
Chongqing Eco-City	10	300	Being constructed
Guiyang Eco-City	9.6	170	Being constructed
Kunming Eco-City	160	950	Being constructed and operated

Table 2: The first batch of national level eco-city pilot projects

This research will use 'eco-city' to represent all the efforts that try to create an urban development model which is ecologically sound, economically feasible and socially satisfied. Furthermore, this research is focused on the Key Performance Indicator (KPI) systems of eco-cities. Literature review indicates that there is little research conducted in this area. This paper will take a comparison study between various KPI systems, currently being applied to eco-city development in China, including international rating systems, national standards and local practices. But before this process it is essential to understand the origin of urban indicators and ratings systems in relation to this study.

1.5 Eco-city indicator development

Cities can be defined by population, by administrative jurisdictions, by functions and by territory. As cities have evolved, so has population increased with associated increase in knowledge, improvement in science and technology but so has the carbon foot print. This has ranged from increased demand in energy supply to environmental and ecological damage to the surroundings. These are but a few of the very reasons why a pursuit of sustainable development emerged, with the eco-city being one of the conceptual manifestations of this quest (Lehmann 2015). However, as far as sustainability is concerned various programs and projects of cities exist with self-proclaimed titles of meeting the criteria of what is termed or described as sustainable by the Brundtland report or eco-friendly by developers (Flynn, 2016). It then becomes imperative to reveal the truth behind these claims as well as compare what a city is doing better in the quest to towards sustainable development (Voula, 2005). As such to achieve and repeat eco- cities status it is essential to understand what recipe was used, with the aim of quantifying sustainability progress. In essence understanding the successes and failures in initiatives, better equip future development and in the case of working principle can lead to a repetition of such initiative, keeping into consideration the contextual understandings. As such, indicators, termed as the recipe plays a vital role in achieving this not only for Eco cities but various other frameworks including NSATs initiative and other conceptual cities.

Indicators are generally described to provide information about a known phenomenon (Guy and Kibert, 1998). It is also described by the World Bank as performance measure that combines information to usable forms. In essence they are described as being the summation of complex situations, which provide an indication of the problem at hand (Premalatha et al. 2013). As relates to eco- city, indicators and sub indicators are used to define the problems to be addressed in order to achieve the prescribed ecological, social and economic aims. In essence the indicator can be used to determine the route or direction to be taken to address the problem, usually based on empirical, quantitative and sometimes qualitative evidence and driven by the theme of the project in question (Reed 2006). According to Keirstead (2007) indicators have to 2 critical roles, they reduce the amount of data used to describe the situation and the promoting or facilitating communication between the audiences. A good example is Alberti (1996), where the concept of ecology is used is in pursuit of urban sustainability. This is described as the total natural flow that a city requires in attaining its long term requirements of the populaces. In the development of this definition, Alberti (1996) emphasizes the need of indicators to establish clear linkages between urban pattern and natural resource base with evidence being scientifically founded, implementation being policy relevant and applicability being readily Justifiable for planning.

In summary, As eco-cities are concerned, indicators is a method of simplicity derived from scientific evidence used to inform the audience on key directions to be taken and implemented to achieve ecological and environmental parity in cities with the support of policy sound frameworks and practical usability with in the overall aim of striving towards sustainable urban development (SUD). However, the post Brundtland report era has made SUD unsustainable without the consideration of social and economic dimensions, as such these will be added facet to the description of Eco city indicators. As such indicators used for their contextual aim of achieving any conceptual city goal will be termed Key Performance Indicators (KPI).

2. NEIGHBORHOOD SUSTAINABILITY ASSESSMENT TOOLS (NSATs)

NSATs evolved from environmental building assessment tools. These tools where established 2 decades ago on the environmental motivations highlighted in the Brundtland Report, however they have been initially focused on buildings with tools such as BREEAM New Construction and LEED New construction being developed and with the Evolutionary extension being BREEAM Community and LEED Neighbourhood (Nguyen, 2011). This extension was largely based on the widening scope covered by sustainability which shifted from environmental to social and economic. As such, the inability of buildings assessment to address abstract and community based elements such as connectivity and transport infrastructure and urban form as well as principles like urban heat Island effect (UHIE), led invariably to the development of NSATs (Sharifi, 2014). Similar to the concept of cities these Neighbourhood based tools are governed by indicators, which has been largely identified by experts to be context specific i.e. rooted to locale and location of development but also exhibit universal traits based on global and more uniform environmental and economic issues such as improving employment rate, reducing poverty levels and dampening the effects of climate change. As such Ameen et al. (2015) categorises indicators into common and local urban context with argument that there exist no specific indicators that suits all countries but however, perhaps we can establish a concept which does not suit all locales but developed to suit specific concepts such as Eco or smart indicators.

2.1 Current urban scale KPI systems in China

An urban area physically encompasses multiple buildings and their sites, and the public environment such as roads, open spaces, and landscaping features which exist in between those sites. It also embraces socio-economic features such as social interactions that are generally more intensive at this spatial scale. Currently there are several urban sustainability rating systems being applied at urban scale such as LEED-ND and BREEAM-Communities. As mentioned earlier, they all represent a larger scale of the built environment beyond single building sites and can be applied to any 'organized urban area' that is beyond a single building site. Both LEED and BREEAM have been used in China, for example, 7 projects were certified by LEED-ND in 2012 with a minimum construction area of 200,000 square meters and a maximum of 3.28 million meter square (Green Building Map, 2015).

In China, there are two main eco-city related national standards, which are known as 'National Standards for Eco Garden City' from MOHURD and 'National Eco-District/County Standards' from Ministry of Environmental Protection (MEP). Both of them use KPIs to evaluate environmental performance of urban areas. Currently 11 cities, including Hangzhou, Suzhou and Guilin, have been selected as "National Eco-Garden Pilot Cities" by MOHURD. Moreover, forty-six cities, counties, and districts have been designated by MEP as national "Eco-counties" or "Eco-districts".

At local level, some eco-city projects have launched their own KPI systems to make them more specific to the local contexts. Often these local systems are more ambitious and have higher requirements in comparison with the national standards. For example, all buildings must be certified by a green building rating system required by SSTEC and Wuxi Eco-City; minimum 20% energy consumption must be sourced from renewables in SSTEC and 8% is required in Wuxi Eco-City New City. These indicators and their corresponding benchmarks have not been incorporated in the national standards, which are more focused on urban infrastructure and pollution control.

2.2 Comparison study between urban scale KPI systems

This section will conduct a comparison study between the international urban rating systems, eco-city related national standards and local eco-city KPI systems. The purpose is to identify the common issues as well as the individual issues from these KPI systems. This would be helpful for informing future eco-city projects to develop their own KPI systems. These KPI systems reviewed include LEED-ND, BREEAM-Communities, National Eco Garden City Standard, National Eco-County/District Standard, SSTEC, Wuxi Eco-City, Changsha Eco-City and Tangshan Eco-City. The four local initiatives are all recognized as the national eco-city pilot projects by in 2013. The main reason for selecting these KPI systems lies in the fact that they all have been implemented in China's urban sustainability development and represent the efforts from both the central government and the local governments. Some key features of the KPI systems reviewed are presented in Table 3.

System features	LEED-ND	BREEAM Communities	National eco-garden city	National eco-city	Tianjin	Tangshan	Changsha	Wuxi
Developer	USGBC	BRE	MOHURD	MEP	Blue Path	SWECO	CABR	ARUP
Purpose	Labeling	Labeling	National assessment	National assessment	Guiding planning & management	Guiding planning & management	Guiding planning & management	Guiding planning & management
Approach	Point score	Point score	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark
Application	New/existing urban area	New/existing urban area	Existing urban area	Existing urban area	New urban area	New urban area	New urban area	New urban area
Structure	3 layers	3 layers	3 layers	3 layers	3 layers	3 layers	3 layers	3 layers
Number of categories	5	6	4	3	4	7	8	7
Number of indicators	56	41	22	19	26	141	47	62
Indicator decomposition	No	No	No	No	Yes	Yes	N/A	N/A
Timeframe	2007	2009	2004	2007	2010	2011	2013	2013

Table 3: The key features of the KPI systems reviewed (source: Based on the authors' elaboration)

All these KPI systems reviewed have a similar structure. They all adopt multi-level approach (i.e. categories, indicators and benchmarks) to evaluate the overall urban sustainability performance. All of them have a number of indicators and corresponding benchmarks, which are classified into different assessment categories. It should be noticed that the number of indicators varies greatly between different systems. The Tangshan Eco-City has the greatest number of indicators: 141 indicators being classified into 7 assessment categories. The National Eco-city Standard issued by MEP has the least number of indicators with only 19 categorized into 3 assessment categories. The use of a greater number of indicators may complicate the data collection and assessment process, and in some cases, it may weaken the overall goal (Zhou et al, 2012). However, on the other hand, small number of indicators may not be sufficiently enough for a comprehensive evaluation.

Table 4 presents the assessment categories from the KPI systems reviewed in this study. It is apparent that all of them try to take a comprehensive view on sustainability by addressing environment, society and economy simultaneously. Land use, infrastructure, transport, resource and energy are some common themes in these systems. The comparison of the assessment categories only gives a vague idea on the scopes of different KPI systems. Opinions diverge on what aspects of an assessment category should be examined, i.e. what indicators should be employed to interpret an assessment category. Thus, further analysis is needed to explore individual indicators included in these assessment categories.

National Standards		International Standards	
MOHURD	MEP	LEED-ND	BREEAM-Communities
Living Environment	Social Development	Regional Priority	Governance
Natural Environment	Environment Protection	Neighborhood Pattern and Design	Social and Economic Wellbeing
Infrastructure	Economic Development	Smart Location and Linkage	Resource and Energy
		Green Infrastructure and Buildings	Land Use and Ecology
		Innovation and Design Process	Transport and Movement
			Innovation
Local Eco-Cities			
Tianjin	Tangshan	Changsha	Wuxi
Society	Urban Function	Green Culture	Society Harmony
Environment	Water Resource	Urban Planning	Urban Function
Resources	Energy	Ecological Environment	Ecological Environment
Economy	Waste Management	Energy	Energy and Resource
	Landscape and Public Spaces	Water Resource	Green Transport
	Transportation and Communication	Solid Waste	Green Building
	Building and Building Industry	Transport	
		Green Building	

Table 4: Assessment categories in different KPI systems

It is challenging to put the indicators side by side and conduct comparisons directly between them. Some systems generally have similar assessment categories (e.g., society, resource, transport, ecology, energy), but the number of indicators and their corresponding benchmarks included within each assessment category varies widely across the systems. Different systems also often classify similar indicators and benchmarks under different categories. For example, LEED-ND classifies the indicators used to measure building performance into Green Infrastructure and Buildings, while they are categorized into Resource and Energy in BREEAM-Communities. Alyami and Rezgui (2012) analyze the similarities and differences of 4 different green building rating systems by consolidating the initial categories and indicators into new schemes. Thus, using Alyami and Rezgui (2012) method of classification all the indicators from the 8 KPI systems reviewed in this research are roughly classified into six broad urban sustainability assessment categories to facilitate comparisons. These assessment categories comprise Culture and Economy, Ecology and Livability, Site and Planning, Resource and Environment, Green Building and Infrastructure, and Traffic and Linkage.

Table 5 shows each of the assessment categories encompasses a number of sustainability issues that are synthesized from the eight urban KPI systems currently being used in China. In total there are 44 individual sustainability issues drawn out from maximum of 141 possible indicators. Such a framework allows evaluation of the convergence and divergence of various KPI systems and further identification of both the contextual issues and specific issues. The box will be ticked if an issue is addressed by a KPI system. If an issue is addressed in 6 or above systems it will be singled out as a common issue. On the contrary an issue is seen as specific if it is included in 3 or below systems. Such an effort is useful to understand how the current eco-city KPI systems work and how they inform the development of future eco-city KPI systems. Table 6 indicates the level of convergence of the KPI systems to the proposed framework by examining the number of issues addressed in each of the KPI systems reviewed.

	MoHURD	MEP	Tianjing	Tangshan	Changsha	Wuxi	LEED ND	BREEAM Commnities
Culture & Economy (7)								
Business Development				✓			✓	✓
Regional Coordination			✓				✓	✓
Cultural Inheritance	✓		✓	✓			✓	✓
Inclusive Community	✓		✓	✓	✓	✓		✓
Sustainable Property Management				✓	✓	✓	✓	
Social Security (Housing & Employment)	✓	✓	✓	✓	✓	✓	✓	✓
Green Economy	✓	✓	✓			✓		
Ecology & Livability (11)								
Ecological Greening & Landscape	✓	✓	✓	✓	✓	✓	✓	✓
Public Space	✓	✓	✓	✓		✓	✓	✓
Public Satisfaction	✓	✓			✓	✓		✓
Shaded Street						✓	✓	✓
Adaptability to Climate Change								✓
Site Environment (Wind & Solar radiation)				✓	✓	✓	✓	✓
Acoustic Environment	✓	✓	✓	✓		✓		✓
Accessibility to Communal Facilities	✓	✓	✓	✓	✓	✓	✓	✓
Diversity of Species	✓		✓	✓	✓	✓	✓	✓
Green & Facilitated Community					✓	✓	✓	✓
Risk Management (e.g. flood)	✓			✓			✓	✓
Site & Planning (3)								
Mixed-Use Development			✓	✓	✓	✓	✓	✓
Land Use & Planning	✓			✓	✓	✓	✓	✓
Site & Neighborhood Scale				✓	✓	✓	✓	✓
Resource & Environment (10)								
Carbon Emission Reduction		✓	✓	✓				✓
Water Resource Management	✓	✓	✓	✓	✓	✓	✓	✓
Energy Management		✓		✓	✓	✓	✓	✓
Waste Management	✓	✓	✓	✓	✓	✓	✓	✓
Outdoor Air Quality	✓	✓	✓			✓		
Low Impact Construction Materials				✓	✓	✓	✓	✓
Natural Environment Protection	✓	✓	✓	✓	✓	✓	✓	✓
Daylight Utilization				✓		✓		
Heat Island Effect	✓			✓		✓	✓	✓
Unconventional Water Source Utilization	✓		✓	✓		✓	✓	✓
Green Building & Infrastructure (9)								
Passive Solar Design				✓			✓	✓
Green & Civilized Construction Plan					✓	✓	✓	
Intelligent Building Management System				✓	✓			
Green Building	✓		✓	✓	✓	✓	✓	✓
Artificial Lighting Design	✓			✓			✓	✓
High-Efficiency HVAC System				✓		✓	✓	✓
Renewable Energy Utilization	✓		✓	✓	✓	✓	✓	✓
Regional Energy Supply Planning	✓	✓	✓	✓	✓	✓	✓	✓
Building Energy Consumption	✓	✓	✓	✓	✓	✓	✓	✓
Traffic & Linkage (4)								
Public Transport Facilities	✓		✓	✓	✓	✓	✓	✓
Green Transport	✓		✓	✓	✓	✓	✓	✓
Transportation Demand Management							✓	✓
Accessibility to Public Transport				✓	✓	✓		✓

Table 5: Eco-city development index checklist

	MOHURD	MEP	Tianjin	Tangshan	Changsha	Wuxi	LEED - ND	BREEAM Communities
Culture & Economy (7)	4	2	5	5	3	4	5	5
Ecology & Livability (11)	7	5	5	7	6	9	8	11
Site & Planning (3)	1	0	1	3	3	3	3	3
Resource & Environment (10)	6	6	9	9	5	9	7	8
Green Building & Infrastructure (9)	5	2	3	8	6	6	8	7
Traffic & Linkage (4)	2	0	4	3	3	3	3	4
Total Sustainability Coverage (44)	25	15	27	35	26	34	34	38
Sustainability Coverage (%)	56.8	34.1	61.4	79.5	59.1	77.3	77.3	86.4

Table 6: Sustainability coverage of the KPI systems reviewed

Table 7 shows the common issues and specific issues identified according to the methodology discussed earlier on. In total 20 issues are regarded as common issues. Among them, eight issues are addressed by all of the systems. These issues are:

- Social security (housing and employment)
- Ecological greening and landscape
- Accessibility to community facilities
- Water resource management
- Waste management
- Natural environmental protection

- Regional energy supply planning
- Building energy consumption

Common Criteria (20)	Specific Criteria (9)
Culture & Economy	
Inclusive Community	Business Development
Social Security (Housing and Employment)	Regional Coordination
Ecology and Livability	
Ecological Greening and Landscape	Shaded Street
Public Space	Adaptability to Climate Change
Acoustic Environment	
Accessibility to Communal Facilities	
Diversity of Species	
Site and Planning	
Mixed-Use Development	
Land Use and Planning	
Resource and Environment	
Water Resource Management	Daylight Utilization
Energy Management	
Waste Management	
Natural Environment Protection	
Unconventional Water Source Utilization	
Green Building and Infrastructure	
Green Building	Passive Solar Design
Renewable Energy Utilization	Green and Civilized Construction Plan
Regional Energy Supply Planning	Intelligent Building Management System
Building Energy Consumption	
Traffic and Linkage	
Public Transport Facilities	Transportation Demand Management
Green Transport	

Table 7: Identification of common issues and specific issues

3. DISSCUSSION

From Table 6, we can see BREEAM-Communities and Tangshan Eco-City have the greatest convergence rates with 86.4% and 79.5% respectively. The two national eco-city related standards have the least of 34.1% and 56.8%. The examination of convergence gives an indication of the comprehensiveness of an eco-city KPI system. It seems that the international assessment systems have a broader view on urban sustainability, while the national standards are more limited to environmental and resource issues. The different assessment coverage between them may be due to their intended roles. The international rating systems are used to certify urban sustainability performance which requires greater involvement of social and economic consideration to present a full sustainability assessment. The national standards are set to assess the environmental performance of existing urban contexts, thus they attempt to involve indicators which are easy to collect data from the current statistical sources. This would avoid data inconsistences between cities which are under assessment. So it is not a surprise that they attempt to involve more environmental and resource issues which are well recorded in the current statistical databases. This also may be attributed to the fact that the national standards were published by MOHURD and MEP separately and both have their own definitions on eco or green city. The four local KPI systems are designed to guide the whole development process of a new city project from planning, design to operational management. Thus they need to consider the local contexts as well as include those internationally (e.g. carbon emission) and nationally recognized indicators (e.g. air pollution, water pollution).

The eight issues, addressed in all systems reviewed, reflect the common concerns for eco-city development in China. It is noted that two issues, i.e. Social Security and Accessibility to Community Facilities, are addressing the socio-economic dimensions of sustainability. The rest are mainly related to the environmental and resources dimension. The other 12 common issues are included in 6 or 7 systems. It is not surprising that the main environmental issues, ranging from energy, water, wastes, land-use to site preservation. These issues are seen as common practice in eco-city development. Mixed-use development is fundamental to urban sustainability as it will help to form an inclusive community and provide employment opportunities to local residents. Moreover, it directly affects travel behavior and enhances walkability to local facilities. Such major impacts will lead towards achieving a more healthy and livable urban environments, resulting in promoting quality of life and well-being of the communities. Furthermore, the provision of Green Landscape, Public Space, and Community Facilities plays an important role in urban sustainability. It can encourage people to interact and forge a sense of community, and improve resident satisfaction. These issues are crucial for new urban developments to attract residents. In addition, green landscape can provide local habitat, facilitate the use of rainwater and increase walking. Providing Public Transport Facilities can effectively reduce car dependence which is a key priority of urban sustainability. Green Building Certification has also become a compulsory requirement in eco-city development as building energy consumption is a significant factor determining the energy performance of a city. All the four eco-city projects require buildings to be certified by a green building rating system, such as LEED or China Green Building Evaluation System.

In addition to the common issues, there are nine specific issues that are used by 3 or below systems. However, this does not mean those issues are less important. These issues represent the divergent part of KPI systems currently being used in China. The lack of commonality in the use of these specific issues can be attributed to the following 2 factors, including:

- Purpose: labeling, national standards and local initiatives assessment;
- Local contexts.

Most specific issues are also relevant to some specific building technologies, such as, passive solar design, daylight utilization, building intelligent system and shaded streets. The involvement of such technologies would be depending on the local conditions, e.g. cost and adaptability of technologies.

4. CONCLUSION

KPI systems have played an important role in guiding the current eco-city development in China. This study elaborates the importance of KPI systems in the planning system as a potential mean to achieve sustainable eco-development. The analysis of the current eco-city related KPI systems indicates that they have different assessment focuses and priorities; however, there are still some convergences from the issues commonly addressed by the KPI systems reviewed. Future eco-city KPI systems may need to consider these common issues, and incorporate the local contexts in tandem.

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